



**UNIVERSITI PUTRA MALAYSIA**

**ASSESSMENT OF MICROWAVE REMOTE SENSING TECHNOLOGY  
(NASA'S AIRSAR-TOPSAR DATA) FOR FOREST TYPE  
CLASSIFICATION ON TIOMAN ISLAND,  
PAHANG, MALAYSIA**

**SEBASTIAN CHEW**

**FH 2000 1**

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(NASA'S AIRSAR-TOPSAR DATA) FOR FOREST TYPE CLASSIFICATION  
ON TIOMAN ISLAND, PAHANG, MALAYSIA**

**By**

**SEBASTIAN CHEW**

**Thesis Submitted in Fulfilment of the Requirements for the  
Degree of Master of Science in the Faculty of Forestry  
Universiti Putra Malaysia**

**June 2000**



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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**SEBASTIAN CHEW**  
**June 2000**

**Chairman : Capt. Professor Dr. Kamaruzaman Jusoff**

**Faculty : Forestry**

Active microwave remote sensing is able to provide information about land surface and forest canopy that would otherwise be unobtainable in regions where cloud cover and darkness prevail. The general objective of this study is to assess the capability and applicability of NASA's airborne SAR (AirSAR) data to classify and map tropical forests utilizing the Environment for Visualizing Images (ENVI) image processing software. The specific objectives are to test the applicability of TOPSAR in classifying forest types of Tioman Island applying standard classification method, generate a digital topographic map, generate a DEM of the study site and produce a forest-type map of Tioman Island. The island is approximately 13,354 hectares. AirSAR's Topographic SAR (TOPSAR) data of the entire island comprising of two strips were acquired on a 3<sup>rd</sup> December 1996 flight mission. Prior to analysis, the image had to be despeckled to remove noise. Five adaptive filters were used and the Gamma filter with an 11x11 window produced the best visual results after initially applying image contrast stretching. Preliminary ground survey revealed that the island has at least five main vegetation types identified as primary forest, beach forest, secondary forest, coconut palm plantation and mangrove forest. Two methods of interpretation were applied. In the first method, visual interpretation was initially

applied where distinct different tones and texture were designated as a “Region of Interest” (ROI) for signature extraction. 16 ROIs were created to represent four vegetation covers and polarization signatures for each ROI were generated. Extracted polarization signatures showed no specific signature or pattern for a particular known forest type. The second method, unsupervised classification, initially yielded 10 classification classes. However, only two land cover classes were readily distinguished and these could be classified as primary and secondary forests. An additional classification obtained is cleared land or developed land. It is therefore suggested that fully Polarimetric SAR data be used together with the TOPSAR.

Additionally, the data sets were registered to the Malaysian RSO projection based on the topographic map for Tioman Island, map sheet 111 (series L7010) and then mosaicked to show the entire island. The VV-polarized C-band enabled the generation of a digital topographic map, as well as slope and relief thematic layers. These information enabled the development of a DEM which in turn enabled three dimensional presentation of the study site. The classification and interpretation results suggest that data acquired using NASA/JPL’s TOPSAR sensor is not adequate in forestry application when applying standard image processing procedures. The application of other techniques such as band math and image differentiation should be tried. Nevertheless, the ENVI software is found to be a relatively easy software to master and is a powerful image processing tool.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk Ijazah Master Sains

**PENILAIAN TEKNOLOGI PENDERIAAN JAUH GELOMBANG MIKRO  
(DATA AIRSAR-TOPSAR NASA) UNTUK PENGKELASAN JENIS HUTAN  
DI PULAU TIOMAN, PAHANG, MALAYSIA**

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Penderiaan jauh menggunakan gelombang mikro aktif membolehkan maklumat-maklumat mengenai permukaan bumi serta silara hutan diperolehi di mana kaedah lain tidak memungkinkannya, terutama di kawasan yang sentiasa diliputi awan ataupun kegelapan. Objektif umum kajian ini adalah untuk menilai keupayaan serta kemampuan data AirSAR NASA untuk mengklasifikasi dan memeta hutan tropika menggunakan perisian ENVI. Objektif khususnya pula adalah untuk menilai kebolegunaan data AirSAR dalam mengklasifikasi jenis-jenis hutan Pulau Tioman serta menghasilkan satu peta jenis hutan untuk Pulau Tioman. Pulau ini meliputi kawasan seluas 13,354 hektar. Data TOPSAR daripada AirSAR meliputi keseluruhan pulau merangkumi dua jalur diperolehi dalam penerbangan pada 3<sup>hb</sup>. Disember 1996. Sebelum menjalankan penganalisan, imej berkenaan harus dibersihkan untuk menghilangkan “kebisingan”. Lima jenis penyaring imej telah dipertimbangkan dan penyaring jenis Gamma dengan tettingkap 11x11 menghasilkan keputusan visual terbaik selepas mengenakan serakan perbezaan bandingan. Peninjauan awal lapangan menunjukkan bahawa pulau ini mempunyai sekurang-kurangnya lima jenis tumbuhan iaitu hutan-hutan primer, pantai, sekunder, dan bakau, serta ladang kelapa. Dua kaedah penginterpretasi telah digunakan. Dalam kaedah pertama, corak polarisasi

telah dihasilkan dengan memilih “kawasan-kawasan tumpuan” (ROI) yang mempamerkan perbezaan ketara dari segi ton dan tekstur melalui interpretasi visual. Sejumlah 16 ROI dikenalpasti yang mewakili empat jenis tutup bumi dan corak polarisasi dihasilkan. Namun begitu, keputusan menunjukkan bahawa pola polarisasi tidak menunjukkan sebarang perbezaan yang ketara baik dari segi nilai mahupun corak pola antara jenis-jenis hutan. Kaedah tak terselia pada awalnya memperoleh 10 kelas pengkelasan. Namun, hanya dua kelas tutup bumi yang boleh dibezakan iaitu hutan primer dan hutan sekunder. Dengan itu, dicadangkan supaya data SAR berpolarimetri penuh digunakan bersama data TOPSAR.

Sebagai tambahan, set-set data tersebut telah didaftarkan kepada unjuran RSO Malaysia berdasarkan peta topo untuk Pulau Tioman, lembaran 111 (siri L7010) dan dicantumkan untuk memperoleh imej lengkap seluruh pulau. Gelombang C berpolarisasi VV telah membolehkan penghasilan satu peta topografi digital. serta lapisan-lapisan bertemakan kelandaian dan tonjolan-tonjolan muka bumi. Maklumat-maklumat ini seterusnya membolehkan penjanaan satu model ketinggian digital (*DEM*) yang mana telah membolehkan kawasan kajian dipersembahkan dalam 3-Dimensi. Keputusan pengkelasan serta penterjemahan mencadangkan bahawa data yang diperolehi menggunakan penderia TOPSAR oleh NASA/JPL adalah tidak memadai dalam aplikasi perhutanan apabila mengguna kaedah pemprosesan imej biasa. Penggunaan kaedah lain seperti *band math* dan *image differentiation* harus dijalankan. Namun demikian, perisian ENVI didapati agak mudah dipelajari serta suatu alat pemprosesan imej yang berkeupayaan.

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I certify that an Examination Committee met on 30<sup>th</sup> June, 2000 to conduct the final examination of Sebastian Chew on his Master of Science thesis entitled “Assessment of Microwave Remote Sensing Technology (NASA’s AirSAR-TOPSAR Data) for Forest Type Classification on Tioman Island, Pahang, Malaysia” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



Sebastian Chew

Date: 8/7/2000

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## LIST OF ABBREVIATIONS

2-D	two-dimensional
3-D	three-dimensional
AIRSAR	Airborne Synthetic Aperture Radar
C	C-band
CD-ROM	compact disk read only memory
DC-8	Douglas Commercial aircraft – model 8
DEM	digital elevation map
EM	electromagnetic
ERS-1	European Remote Sensing Satellite 1
ERS-2	European Remote Sensing Satellite 2
GCP	ground control point
GIS	geographic information system
GPS	Global Positioning System
HH	horizontal polarized transmission, horizontally polarized reception
HV	horizontal polarized transmission, vertically polarized reception
JERS-1	Japanese Earth Remote-Sensing Satellite
JPL	Jet Propulsion Laboratory
L	L-band
LANDSAT	Land Satellite
NASA	National Aeronautics and Space Administration
P	P-band
RADAR	radio detection and ranging
RADARSAT	Radar Satellite
SAR	synthetic aperture radar
SIR-A	Shuttle Imaging Radar-A
SIR-B	Shuttle Imaging Radar-B
SIR-C	Spaceborne Imaging Radar-C
SIR-C/X-SAR	Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar
SPOT	Système Probatoire d’Observation de la Terre
TM	Thematic Mapper
TOPSAR	Topographic Synthetic Aperture Radar
VV	vertically polarized transmission, vertically polarized reception

## **CHAPTER I**

### **INTRODUCTION**

#### **General**

Forest is a major renewable natural resource which generates a significant economic contribution to the country, not only from timber produce but also from non-timber products and services. The services include contribution towards environmental stability and protection as well as amenity and recreation. These continued flow of benefits could only be maintained with sustainable management to ensure the forests' survival. Globally, the forest is a vital component of the whole earth's ecosystem balance as they contain about 90% of the carbon in terrestrial vegetation (Ismariah and Garcia, 1998). The shifts in forest mass or their clearing is the second major source of increase in atmospheric carbon.

Natural resource managers including foresters require a wide variety of information about the geographical boundaries as well as the characteristics and conditions of the forest ecosystems. Therefore, a comprehensive, accurate and up-to-date database together with a highly efficient monitoring tool or system is critical for any development, and eventually the implementation of management strategies. Under these circumstances and the consequence arising from it, there exists an urgent need for effective conservation as well as sound management systems and strategies. As a tool to accomplish the management plans, remote sensing technology has proven to be a vital component in enhancing and strengthening the entire development of forest management system. Furthermore, the ability to predict environmental hazards stemming from development activities is of importance to safeguard, not only human

lives, but also the natural environment as a whole. So far the immediate and quickest answer to this task is through remote sensing.

### **Justification**

Information and their degree of accuracy form the basis for planning of every kind. Remote sensing technology has been used in forest type classification and inventory since taking pictures from aircraft utilising high resolution panchromatic and/or infrared cameras were founded. The advancement in technology, notably space technology, has seen the deployment of the Earth Resources Technology Satellite (ERTS), or what is commonly known today as Landsat, on July 23 1972 (Harper, 1976; Taranik, 1985; Drury, 1990), the first of numerous specifically designed imaging satellites for studying the earth's resources. These satellites capture images of the earth within the visible and infra red wavelength of the electromagnetic spectrum.

However, this has been and remains a serious handicap for permanently cloudy tropical countries especially during the rainy seasons, or in polar regions where long periods of darkness prevail. Apparently, with this in mind, remote sensing application involving the use of active microwave sensors, manipulating electromagnetic energy which lie within the wavelength range of 1 to 1000 mm, was looked upon to solve this predicament and eventually has become an increasingly important area of remote sensing. Microwave remote sensing is important in particular due to its independence of sun illumination and little or no effect from the atmosphere and clouds. In other words, active microwave remote sensing can provide

information about the land surface and forest canopy that would otherwise be unobtainable.

Much has been discovered and learned over the last few decades concerning the advantages as well as the limitations from using optical remotely sensed data for assessing and monitoring our forests and other natural resources. Radar remote sensing, up to some point, is the best solution to limitations encountered with optical data.

### **Objectives**

The general objective of the study is to assess the potential application of the microwave remote sensing technology for forest type classification in Tioman Island, Pahang. The specific objectives are :-

1. to test the applicability of topographic SAR (TOPSAR) data in classifying forest types of Tioman Island using standard classification method
2. to generate a digital topographic map
3. to develop a digital elevation model of the study site
4. to produce a forest-type map of Tioman Island through ‘unsupervised classification’ method

### **Scope of the Study**

The study was carried out on Tioman Island, off the coast of the state of Pahang, Malaysia. The American National Aeronautics and Space Administration (NASA)-Airborne Synthetic Aperture Radar (AirSAR)'s Topographic SAR (TOPSAR) data was assessed for its applicability in forest type detection and mapping by applying standard image interpretation and classification techniques. In addition, the study included assessing the generation of useful topographic information. The software used to process and analyse the data set was the Environment for Visualizing Images (ENVI) version 3.0.

## CHAPTER II

### LITERATURE REVIEW

#### Remote Sensing

Remote sensing in its broadest sense simply means the process of observing/recording/perceiving an object, phenomenon or an area from an indefinite distance, whereby the sensors are not in direct contact with the objects or events. In a more restricted or scientific sense, remote sensing is the art or technique of acquiring information about the earth's surface and atmosphere, through the analysis of data obtained through specialised sensors (Barrett and Curtis, 1976; Curran, 1985; Lillesand, 1987; Maguire, 1989). This definition also includes conventional photography.

The sensors require an intervening medium as a conveyer to relay information emitted or given out by the objects or events being observed. The medium referred to is the electromagnetic radiation (EMR) (Estes, 1974; Goillot, 1980; Lillesand and Kiefer, 1994; Simonett and Everett, 1976) of which are categorised by their wavelength location within the electromagnetic spectrum (Figure 1). The main source of energy for “conventional” or optical remote sensing sensors is visible light which occur between  $0.4\mu\text{m}$  to approximately  $0.7\mu\text{m}$ . Other familiar forms include radio waves, heat, and ultraviolet as well as X-rays. The term remote sensing is used as well in a narrower sense referring to what is known as microwave (1mm to 1m wavelength), the collection of digital data beyond the visible range of the EMR. This narrower definition is used here.

Prior to digital imaging, aerial photographs were analysed, interpreted and/or integrated with ancillary data for a variety of applications in earth resource disciplines which include geology and soil mapping, landuse/cover mapping, agriculture and forestry and urban and regional planning and environmental assessment. However, the use of aerial photography, especially where a large area is involved, is deemed time consuming, costly and laborious (Abdul Hamid, 1997; Samarakon *et al.*, 1995). Nevertheless, this technology is still utilised as a continuum of image interpretation systems involving different sensors and different wavelengths of electromagnetic energy.

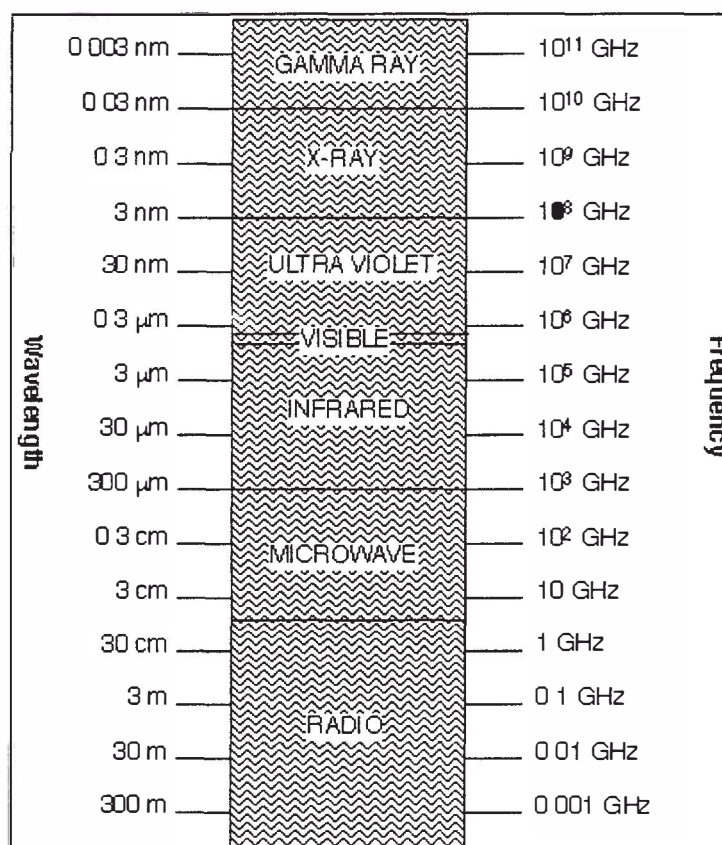


Figure 1: The Electromagnetic spectrum

Remote sensing technology has greatly advanced and therefore serves an increasing number of applications. This is mainly due to the development of better procedures and sensors for capturing, documenting, monitoring and assessing the state as well as changes in the environment as a whole, and the natural resources in particular.

### **Radar**

The word radar was conceived during World War II, by the United States' Navy, as a code name (Eaves, 1987; Avery and Berlin, 1992) and is an acronym derived from the phrase Radio Detection And Ranging (Eaves, 1987). As the name implies, radar was developed as a means of using radio frequency to detect the presence of objects and determine their position. Various forms of radar devices were developed between 1903 and 1925 (Peebles, 1998). In addition to detecting targets, these devices were able to measure the distance to the target. Radar systems are considered to be an active remote imaging sensor as they do not require sunlight for their source of illumination.

### **SAR System**

There are two basic processes involved in remote sensing, namely data acquisition and data analysis (Campbell, 1986). Data acquisition involves the use of sensors to record variations in the way the earth surface features reflect and emit



electromagnetic energy. The data analysis process, on the other hand, examines the acquired data using a computer to analyse digitally sensed data. To assist in data analysis, reference data regarding the resources being studied is to be used when and where possible or available as these data help further in extracting information on type, extent, location and conditions of the resources under study.

Acquisition of remotely sensed data may be done in several ways, using Electromagnetic Radiation (EMR), sound waves or gravity forces (Schwarz, 1985). In the case of this project, remote sensing by EMR was adopted, utilising electromagnetic energy sensors that are currently being operated from airborne and space-borne platforms to assist in inventorying, mapping, and the monitoring of earth resources. Measurement of electromagnetic radiation reflected by an object provides information about the nature and shape of the object. The fact that different objects reflect different amount of radiation and that their spectral characteristics vary, forms the basis for analysis of remotely sensed material.

As explained earlier in Chapter 1 (Justification) and also in this chapter (Radar), radar is an active microwave sensing system in that the sensor supplies its own source of energy or illumination. It transmits a pulse (Figure 2), which is a parcel or packet of photons, of microwave signals in the direction of interest then records and measures the strength and time delay of the returned energy, called “echoes” or “reflections”. The time delay,  $t$ , of the echo can be used to determine the range or distance,  $R$ , to an object, since microwaves travel at the speed of light,  $c$ , and  $R = ct$ . The photons all have the same wavelength (or frequency), which will be in the range 1cm to 1m for radar. The pulse duration (length),  $\tau$ , is typically around 10-50 micro-